EVALUATION OF SEVERAL FORMULATIONS OF MALATHION AS A PROTECTANT OF GRAIN SORGHUM AGAINST INSECTS . . . IN SMALL BINS

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PREFACE

This report presents the results of an experiment with different formulations and dosages of malathion applied to grain sorghum in small bins for protection against attacks by mixed populations of stored-grain insect pests. The scope of these tests was intermediate between small-scale laboratory experiments and full-scale field tests.

The entomological parts of the studies were conducted at the Mid-West Grain Insects Investigations laboratory at Manhattan, Kans. Edwin Dicke, Ralph Ernst, Warren E. Blodgett, Leon Hendricks, and Joseph L. Wilson took part in this work. All of the residue determinations were made by the Chemical Unit, Stored-Product Insects Research and Development Laboratory at Savannah, Ga. These are laboratories of the Stored-Product Insects Research Branch, Market Quality Research Division, Agricultural Research Service.

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EVALUATION OF SEVERAL FORMULATIONS OF MALATHION AS A PROTECTANT OF GRAIN SORGHUM AGAINST INSECTS IN SMALL BINS

By Delmon W. La Hue, *entomologist, Market Quality Research Division Agricultural Research Service*

SUMMARY

Four formulations of malathion were tested for 12 months as protectants of grain sorghum against insect infestation in 5-cubic-foot masonite bins.

Damaging infestations of mixed populations of stored-grain insects were rapidly established in all bins of untreated grain sorghum. When treated with the standard dosage of 1 pint of premium-grade 57-percent malathion emulsifiable concentrate applied as water emulsion to 1,000 bushels, grain sorghum became heavily infested by the sixth month of storage.

A dosage of 2 pints of the malathion emulsifiable concentrate per 1,000 bushels applied as an undiluted low-volume spray afforded excellent protection, although a small amount of damage was inflicted under the high insect population pressures.

A diatomaceous earth, Kenite 2–I, containing 1 pint of malathion (0.555 percent), at a dosage of 112 pounds of dust per 1,000 bushels, also afforded excellent protection. However, the addition of the dust reduced the test weight of the grain sorghum about 2.2 pounds per bushel and consequently lowered the commercial grade.

A dosage of 2 pints of malathion emulsifiable concentrate per 1,000 bushels applied as a high-volume, water-diluted emulsion spray afforded protection only slightly less effective than the 2-pint low-volume concentrate and the 1 pint of malathion in Kenite 2–I dust.

BACKGROUND AND OBJECTIVES

Previous studies were made of grain sorghum with 13.5-percent moisture content stored in small bins for 12 months. These studies indicated that 5 gallons of a water emulsion containing as much as 1.5 pints of premium-grade 57-percent malathion emulsifiable concentrate per 1,000 bushels did not satisfactorily protect the grain sorghum from damage during a continuous exposure to mixed populations of stored-grain insects.[1] This report presents the findings of a study to determine the efficacy of different formulations of malathion applied at selected dosages. The insecticide was applied at 1,000-bushel rates of 2 pints of premium-grade 57-percent malathion emulsifiable concentrate, as an ultra-low-volume mist spray and as a water-diluted emulsion spray, 1 pint of emulsifiable concentrate impregnated in 112 pounds of Kenite 2–I, and the standard 1 pint emulsified in water.

The objectives of the experiment were to compare the effectiveness of the different treatments with one another and with untreated check lots, and to provide data for comparison with past and future small-bin storage studies.

[1] LaHue, Delmon W. evaluation of malathion, synergized pyrethrum, and a diatomaceous earth as protectants against insects in sorghum grain . . . in small bins. U.S. Dept. Agr. Market. Res. Rpt. 781, 11 pp. 1967.

MATERIALS AND METHODS

The experiment was conducted from April 1966 to July 1967. Uncleaned grain sorghum, purchased locally during the 1965 harvest, was stored in a metal bin for 6 months before use. Before being treated, the grain sorghum was run through a small shaker-screen and fan-type seed cleaner to remove dust, plant parts, and other foreign materials. All treatments were applied to 2-bushel lots of grain, and then the grain and malathion were thoroughly mixed by being rotated in a steel barrel on an electric barrel roller at 16 revolutions per minute for 5 minutes (fig. 1).

The standard 1,000-bushel dosage of 1 pint of premium-grade 57-percent malathion emulsifiable concentrate (e.c.), mixed with 39 pints neutral distilled water, was applied with a DeVilbiss HM–521 compressed air spray gun through an aperture in the lid of the rotating barrel. The dosage of 2 pints malathion e.c. with 38 pints of neutral distilled water was applied in the same manner.

The ultra-low-volume application of malathion e.c. at the rate of 2 pints per 1,000 bushels was made by siphon movement through a ¼-inch JN Spraying Systems Co. atomizing nozzle block at 10 pounds per square inch air movement. The block was fitted with No. 1650 fluid and No. 64 air nozzles to deliver a round spray pattern (fig. 2). Acetone was run through the block immediately after the siphoning of the malathion e.c. to insure that all of the malathion was removed from the apparatus and deposited on the grain.

A dust mixture of malathion e.c. impregnated into the diatomaceous earth dust, Kenite 2–I, was applied to 2-bushel lots of grain at a rate of 1 pint of malathion and 112 pounds of

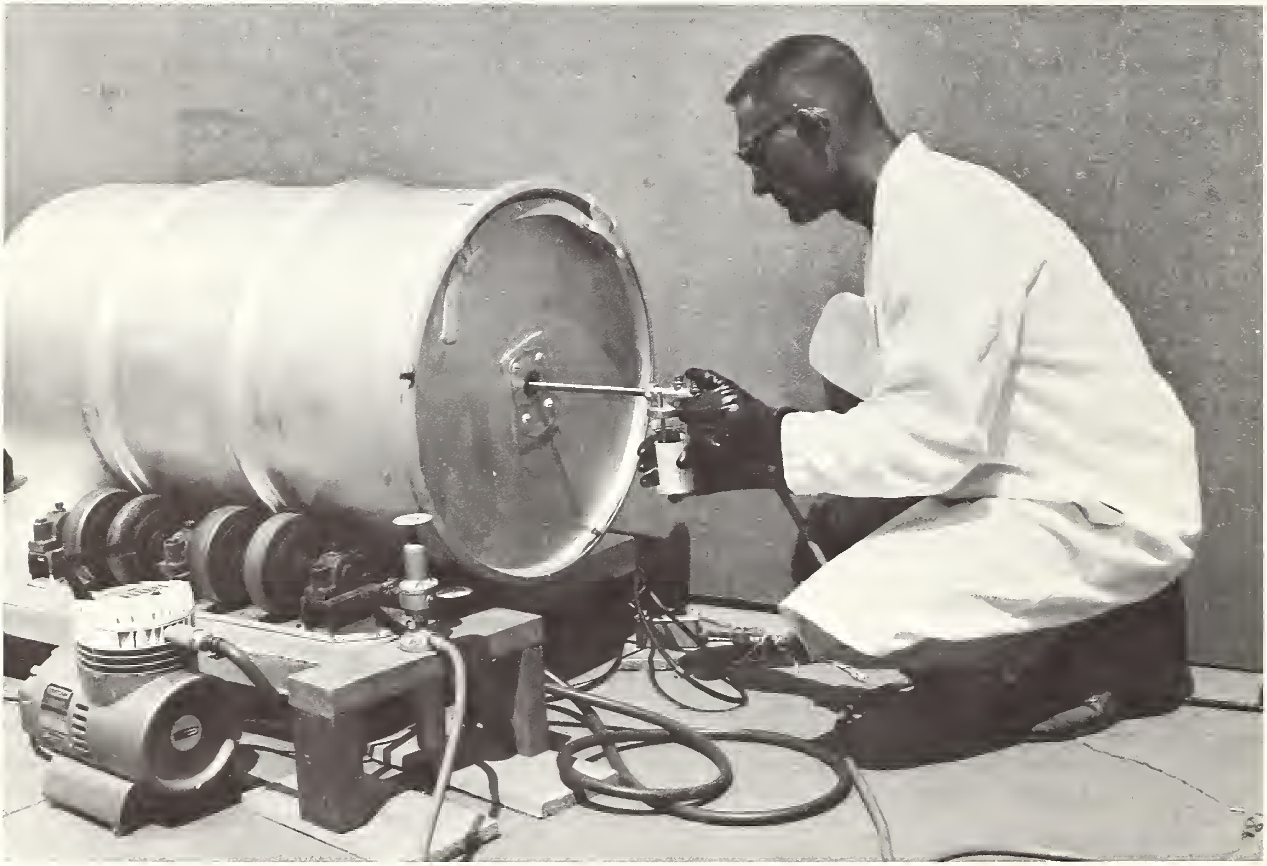

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FIGURE 1.—Application of malathion emulsion spray to grain sorghum in a rotating barrel.

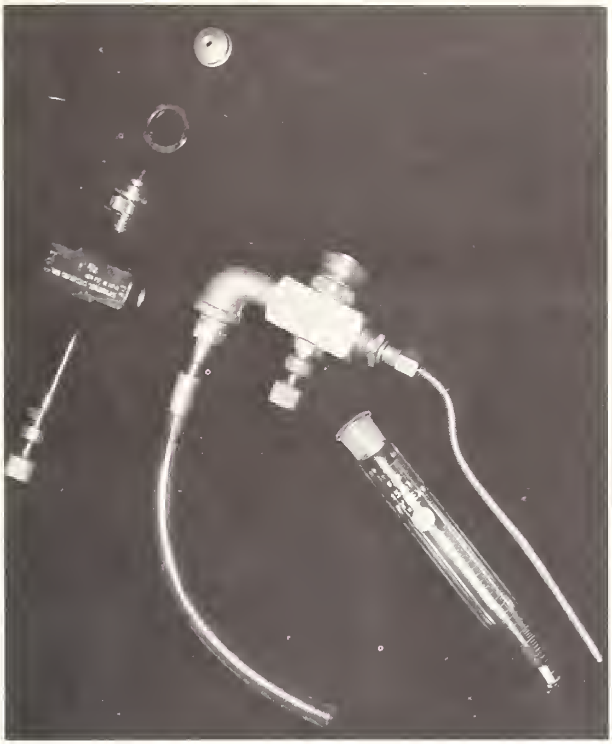

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FIGURE 2.—An atomizing spray nozzle assembly used in ultra-low-volume applications of concentrated insecticides.

Kenite 2–I per 1,000 bushels. The dust mixture contained 0.555 percent malathion. The grain and dust were thoroughly mixed by being rotated in the steel barrel.

Immediately after being treated, two lots—4 bushels—of grain sorghum were placed in a 5-cubic-foot masonite bin (fig. 3). Five replications (bins) of each treatment, with five check bins of untreated grain sorghum, were placed in a five- by five-block arrangement in a 13- by 18-foot room on the first floor of a heated dwelling house. After the bins were filled, the grain surface area of each bin was immediately leveled off 1 inch below the top rim of the bin to provide equal exposure areas in all bins.

The temperature and relative humidity in the infestation room favored insect development throughout the storage period. The temperature ranged in the summer from 96° to 60° F. with an average daily maximum and minimum of 81.5° and 74.4° and in the winter from 84° to 57° with an average daily maximum and minimum of 73.9° and 66.8°. A water-evaporating cooling unit maintained a minimum relative humidity of about 50 percent.

Large numbers of vigorous insects reared on whole and cracked grain sorghum were released in the storage room 14, 34, 49, 110, 196, and 242 days after the experiment was started. About 5,000 adult rice weevils *(Sitophilus oryzae* (L.)), 2,500 adult confused flour beetles *(Tribolium confusum* (Jacquelin duVal)), and 2,500 adult red flour beetles *(Tribolium castaneum* (Herbst)) were scattered in the aisles and around the bins during each major insect release. Lesser numbers of flat grain beetles *(Cryptolestes pusillus* (Schönherr)), saw-toothed grain beetles *(Oryzaephilus surinamensis (L.))*, and Indianmeal moths *(Plodia interpunctella* (Hübner)) in culture jars distributed throughout the storage room emerged during the 4th to 11th months of storage. Although no lesser grain borers *(Rhyzopertha dominica* (F.)) were released in the storage room, large numbers were observed after 8 months of storage. This "wild" infestation had migrated by boring through temporary sealed wood-fiber walls from another storage area.

BN 20671

FIGURE 3.—Small masonite bin used to store grain sorghum samples in testing effectiveness of malathion in preventing insect infestations.

SAMPLING

At the beginning and at the end of the 12-month storage study, composite samples of grain sorghum from each treatment were submitted to the Inspection Branch, Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture, at Kansas City, Mo., for official grade determinations. The initial samples from the untreated bins were considered as representative of the original grain sorghum for grade comparisons.

Excess grain, collected during the bin surface leveling procedures, was used for all samples of grain sorghum immediately after treatment. For repeated tests of the same bins at intervals, samples were taken with a nonpartitioned grain trier or probe 1, 3, 6, 9, and 12 months after treatment. The trier was inserted twice near the center and about 3 inches from the bin wall in each of the four quadrants. These samples of about 1,950 grams per bin were held in sealed 1-gallon glass jars until examination and testing.

As each bin was emptied at the end of the 12-month storage period, duplicate 1-gallon samples were progressively collected from top to bottom. These samples were sifted over a 10-mesh screen to remove the insects, kernel bits, dusts, and insect excrement or frass. The sifted grain sorghum was held in covered jars for 45 days for a record of insect emergence. The screenings were sifted over a No. 20 sieve to separate the frass from the insects and kernel bits. The fine siftings were weighed for an estimation of the extent of insect damage.

At the end of the storage period, a composited 1,000-kernel sample was taken from the samples held for insect emergence to determine (1) the percent of kernels damaged by insects and (2) the kernel weight loss due to insect feeding.

Repellency studies were first conducted with composite samples from the excess grain sorghum removed during the initial leveling of the grain surface in the bin. Repellency after 12 months' storage was studied with grain sorghum obtained during the emptying of the bins. About 500 rice weevils were released in each chamber for dispersal to any of 10 cartons, five of which contained untreated grain sorghum and the other five grain sorghum from one bin treatment (fig. 4).

The grain sorghum temperature in all bins was taken at weekly intervals with a glass thermometer inserted into the center of the grain mass.

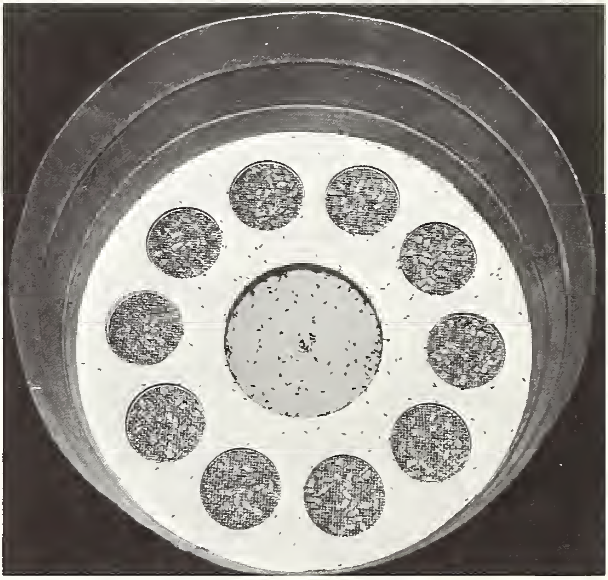

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FIGURE 4.—A repellency test chamber showing dispersal of rice weevils soon after release.

REPETITIVE LABORATORY STUDIES

The samples taken periodically by probing the bins were all handled in the same manner. The live and dead insects were counted for an estimation of the bin populations. The test weight and moisture content of the grain sorghum and the percentage of damaged kernels were determined.

Four 200-gram subsamples from each bin were placed in 1-pint screen-covered glass mason jars for toxicity tests. About 50 adult rice weevils, red flour beetles, confused flour beetles, or lesser grain borers were placed in each jar. All species were from cultures reared in the laboratory. Dead insects were counted 21 days later. All fine dusts removed from the samples by screening during the mortality counts were returned to the respective jars. After the toxicity tests were completed, the subsamples were held an additional 42 days for the emergence of the first generation (F_1) progeny from the rice weevil, red flour beetle, and lesser grain borer toxicity test exposures, and for 49 days from the confused flour beetle exposures. After the F_1 progeny counts, all samples were retained for a visual assessment of damage by the progeny.

As a direct test of their acceptance or avoidance of the grain sorghum protected by the various treatments, about 250 rice weevils were released in the multichoice food preference or selection chambers (fig. 5). In this apparatus, five ½-pint cardboard cartons, one filled with grain sorghum from each of the four different treatments and from the untreated check, were exposed to a dispersal of the rice weevils released in the center depression. The weevils were allowed 24 hours to enter and remain in the cartons with acceptable grain. All subsamples used in the toxicity tests, food preference, and repellency studies, except those taken soon after the initial insecticide treatment, were held in a deepfreeze at −20° F. for 96 hours before being exposed to the insects. This procedure was performed to eliminate the possibility that insects already infesting the kernels might emerge.

One-pint samples of grain sorghum from each bin treated with malathion were submitted periodically for an analysis of the malathion residue.

All grain obtained by probing that was not used for the various laboratory studies was kept for a visual assessment of damage by the progeny developing from the infestations that had been established in the different bins at the time the probings were made.

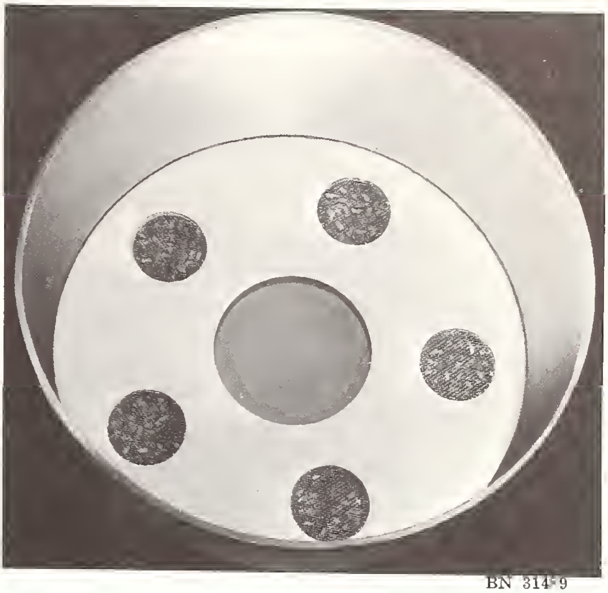

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FIGURE 5.—A multichoice food preference chamber with samples from one untreated and four treated bins of grain sorghum.

RESULTS

Grain Temperatures

The temperature of the grain mass in each bin was taken at weekly intervals by inserting a mercury thermometer to a depth of about 12 inches. Higher temperatures caused by insect activity were noted in bins of untreated grain sorghum during the latter part of the second month (table 1). In the bins of grain sorghum treated with the standard 1-pint application of malathion, insect activity had raised the temperature after 5 months' storage. No temperature rise occurred in any of the bins containing grain sorghum treated with the other formulations.

TABLE 1.—*Average mass temperatures of insecticide-treated grain sorghum during 12 months' storage*

Insecticide and dosage per 1,000 bushels	1 month	2 months	3 months	4 months	5 months	6 months	7 months	8 months	9 months	10 months	11 months	12 months
	° F.	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
Sprays:												
Malathion:												
2 pints:												
Concentrate	71.4	75.8	84.2	80.4	76.5	73.4	70.6	67.0	68.5	69.0	68.5	70.2
Emulsion	71.2	75.6	84.0	80.0	76.3	73.8	70.5	66.0	69.1	68.8	68.5	70.2
1 pint, emulsion	71.2	75.7	84.0	80.4	78.0	78.8	78.9	78.4	80.7	83.8	84.8	87.9
Dust:												
Malathion in Kenite 2–I, 1 pint in 112 pounds	71.4	75.8	84.0	80.2	76.5	73.5	70.1	66.1	68.0	67.7	68.1	70.2
Untreated check	71.8	76.9	91.0	94.2	99.8	101.7	102.3	103.2	102.8	101.0	96.3	90.3

Moisture Content

The moisture content of the bin samples was determined on a Steinlite 512 RC moisture tester. The grain sorghum contained about 12.5 percent moisture when the experiment was started. For the greater part of the storage period, the different lots remained near this level, except during the winter months when the furnace was in constant operation (table 2).

Commercial Grade

The grain graded No. 2 Yellow Grain Sorghum before cleaning. Cleaning by removing the more than 5 percent of the sample that consisted of foreign material, shrunken and broken kernels, and insects, raised the test weight about 1.5 pounds per bushel. This cleaned grain graded No. 1 Yellow Grain Sorghum. Treatment with the diatomaceous earth dust containing malathion reduced the test weight about 2 pounds per bushel; consequently, the grain with this treatment graded No. 2 Yellow Grain Sorghum. Other treatments did not change the numerical grade (table 3).

After 12 months' storage, treatment composites were graded again. The heavily damaged untreated check had 88 percent of the kernels damaged by insects, a sour odor, and a weight of only 39.5 pounds per bushel; consequently, it was determined as Sample Grade—Weevily Grain Sorghum. The sample from the bins treated with the standard 1-pint dosage of malathion had 47-percent kernel damage, a sour odor, and a test weight of only 44 pounds per bushel; it was graded Sample Grade—Weevily Grain Sorghum. Grain sorghum treated with the diatomaceous earth containing malathion graded as No. 3 Grain Sorghum, distinctly discolored. No change in grade occurred in the grain sorghum treated with 2-pint ultra-low-volume malathion concentrate per 1,000 bushels, but that treated with 2 pints as a water emulsion graded No. 2 Grain Sorghum because of 5-percent kernel damage and slightly lowered test weight.

Malathion Residues

The residues recovered from samples taken 24 hours after treatment were much higher than expected (table 4). The explanation probably lies in the method of application used in this test. In contrast to commercial practice, when the insecticide is applied to grain in a rotating barrel, there is no escape of the spray that bounces off the grain. The residues degraded markedly during the first month after treatment, and thereafter declined more or less gradually. The malathion applied in Kenite 2–I degraded much less rapidly than that applied as a water emulsion. The dosages of 2 pints per 1,000 bushels (22.32 parts per million (p.p.m.)) degraded after 3 months' storage nearly to the legal tolerance of 8 p.p.m. for malathion on grain.

Insect Populations

All of the bins containing untreated grain sorghum had noticeable amounts of dust consisting of insect frass and kernel remains sifting out around the unsealed bases after 2 months' storage. Progressively larger amounts were noted until the 10th month, when the

TABLE 2.—*Moisture content of insecticide-treated grain sorghum during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Moisture content						
	Before treatment	After 24 hours	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sprays:							
Malathion:							
2 pints:							
Concentrate	12.42	12.50	12.78	12.29	12.19	11.38	12.04
Emulsion	12.52	12.73	12.98	12.42	12.32	11.59	12.06
1 pint, emulsion	12.60	12.58	12.94	12.30	12.08	11.93	12.09
Dust:							
Malathion in Kenite 2–I, 1 pint in 112 pounds	12.42	12.25	13.02	12.46	12.14	11.65	12.14
Untreated check	12.42	12.51	12.87	12.42	12.17	12.48	12.75

TABLE 3.—*Official grades of grain sorghum before and after insecticide treatments, and after 12 months' storage*

Insecticide treatment and grading interval	Test weight	Moisture	Odor	Damaged kernels	Foreign material, broken kernels	Insects		Insect damage	Official grade, Yellow
						Live	Dead		
	Pounds	*Percent*		*Percent*	*Percent*	*Number*	*Number*	*Percent*	
Before cleaning	57.0	12.7	None	0.9	5.8	6	0	0	No. 2
Untreated—Cleaned:									
After binning	58.5	13.0	None	.5	.1	0	0	0	No. 1
After 12 months	39.5	15.4	Sour	88.0	6.0	48	0	88.0	Sample [1]
Sprays:									
Malathion, 2 pints:									
Concentrate:									
After treatment	59.0	12.7	None	.5	.4	0	0	0	No. 1
After 12 months	58.0	12.0	None	2	2.0	0	45	2.0	No. 1
Emulsion:									
After treatment	58.5	12.7	None	.5	.2	0	0	0	No. 1
After 12 months	56.0	12.0	None	5.0	.5	15	23	4.0	No. 2 [1]
Malathion, 1 pint:									
After treatment	59.0	12.9	None	1.0	.1	0	0	0	No. 1
After 12 months	44.0	14.3	Sour	47.0	1.8	38	0	47.0	Sample [1]
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds:									
After treatment	56.5	12.3	None	0	.2	0	0	0	No. 2
After 12 months	55.5	11.8	None	3.0	.4	0	12	2.0	No. 3 [2]

[1] Weevily.
[2] Distinctly discolored.

TABLE 4.—*Malathion residues recovered from insecticide-treated grain sorghum at given intervals during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Calculated application	Malathion residue after—					
		24 hours	1 month	3 months	6 months	9 months	12 months
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Sprays:							
Malathion:							
2 pints:							
Concentrate	22.32	19.74	11.42	8.78	6.12	4.62	3.44
Emulsion	22.32	18.28	10.20	7.58	5.66	4.00	3.08
1 pint, emulsion	11.16	9.62	4.26	2.40	1.66	.66	.64
Dust:							
Malathion in Kenite 2–I, 1 pint in 112 pounds	11.16	12.80	7.42	4.94	3.64	1.98	2.12

amounts started to decline. After 4 months' storage, dust deposits were quite noticeable around the bins of grain sorghum treated with the 1-pint dosage of malathion; however, the amounts were not nearly as great as around the bins containing untreated grain sorghum. Very little insect frass was evident around any of the other bins.

The numbers of live adult insects recovered from the probe samples from all bins at the specified sampling intervals (table 5) indicate the relative populations within the bins throughout the storage period. After 1 month's storage, 438 active rice weevils, red flour beetles, and confused flour beetles were found in samples from the bins of untreated grain sorghum. After 3 months' storage, 3,564 active insects were recovered from these same bins. During the same two sampling periods, only 51 and 112 live but less active insects were recovered from samples taken from bins of grain sorghum treated with the 1-pint malathion emulsion. After 3 months, the residues on the grain sorghum with this treatment were not enough to control the development of large populations. The residues from both of the 2-pint malathion treatments and from the 1-pint malathion impregnated in Kenite 2–I greatly suppressed the populations throughout the 12 months' storage. The insects, particularly the rice weevils, recovered from the last three treatments were much smaller and less active than those recovered from bins with the much less effective 1-pint malathion application and from the untreated grain sorghum.

Lesser grain borers penetrated the walls of all the bins containing untreated grain sorghum and grain sorghum treated with the 1-pint malathion emulsion. This structural damage was not evident in any of the other bins.

Food Selection Studies

Competitive multichoice offerings of samples from the different treatments to adult (14-day-old) rice weevils showed that the malathion-Kenite 2–I dust treatment made the grain sorghum less desirable as food for the weevils (table 6). Aging of the treated grain did not materially affect the response of the weevils. Whether malathion was applied to the grain sorghum as a concentrate or in a water emulsion did not seem to make a great deal of difference in the acceptability of the grain.

Repellency Tests

Repellency tests were conducted with replicated samples aged for 7 days or for 12 months after treatment. The replicated grain sorghum samples from the bins were compared with cleaned, untreated grain sorghum from the source lot used for all treatments. Malathion applied as a concentrate and in water emulsions did not appear to make the grain repellent to insects. From 45 to 59 percent chose malathion-treated wheat in tests conducted 7 days after treatment, and from 45 to more than 61 percent chose it after 12 months' storage (table 7). The malathion-Kenite 2–I dust treatment did impart repellency to the grain sorghum but not to the high degree previously found (unpublished data) in wheat, shelled corn, and grain sorghum treated with the same dosage of Kenite 2–I alone. Grain from the

TABLE 5.—*Live adult insects recovered from all probe samples of insecticide-treated grain sorghum during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Insects in samples taken after—				
	1 month	3 months	6 months	9 months	12 months
	Number	*Number*	*Number*	*Number*	*Number*
Sprays:					
Malathion:					
2 pints:					
Concentrate	1	23	330	916	533
Emulsion	4	26	780	988	472
1 pint, emulsion	51	112	5,726	4,335	9,625
Dust:					
Malathion in Kenite 2–I, 1 pint in 112 pounds	4	28	453	768	372
Untreated check	438	3,564	13,654	21,171	17,210

TABLE 6.—*Response of rice weevils to insecticide-treated grain sorghum in food selection studies*

Insecticide and dosage per 1,000 bushels	Percentage of weevils that entered samples after storage period of—					
	7 days	1 month	3 months	6 months	9 months	12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sprays:						
Malathion:						
2 pints:						
Concentrate	22.25	19.58	22.93	20.20	18.29	17.22
Emulsion	22.00	20.23	24.43	22.02	20.64	19.77
1 pint, emulsion	23.33	24.14	22.38	25.59	26.02	26.41
Dust:						
Malathion in Kenite						
2–I, 1 pint in 112 pounds	4.92	8.48	8.35	9.34	9.71	7.95
Untreated check	27.50	27.57	21.91	22.85	25.34	28.65

untreated check bins that was heavily damaged after 12 months' storage seemed to be somewhat more repellent than the untreated and undamaged grain.

TABLE 7.—*Repellency of malathion-treated grain sorghum to adult rice weevils 7 days after treatment and after 12 months' storage*

Insecticide and dosage per 1,000 bushels and aging interval	Repellency [1]	Preference shown [2]
	Percent	*Percent*
Sprays:		
Malathion:		
2 pints:		
Concentrate:		
7 days	0.80	49.60
12 months	9.23	45.39
Emulsion:		
7 days	9.16	45.42
12 months	4.80	47.60
1 pint, emulsion		
7 days	−18.60	59.30
12 months	−23.05	61.52
Dust:		
Malathion in Kenite 2–I,		
1 pint in 112 pounds		
7 days	63.74	18.13
12 months	49.61	25.20
Untreated:		
7 days	.40	49.80
12 months	20.16	39.92

[1] Twice the difference between the percentage of weevils that actually did choose the given sample and the 50 percent that would normally be expected to choose one of two equally attractive samples.

[2] Number of weevils in treated grain as a percentage of the total number of weevils in the test.

Toxicity Studies

Bioassay tests were conducted with about 50 rice weevils, red flour beetles, confused flour beetles, and lesser grain borers, each exposed in replicate to subsamples of grain sorghum from the different treatments. In studies conducted 24 hours after the insecticide application all adult rice weevils were killed by all treatments, but a few progeny emerged from the grain sorghum treated with a 1-pint malathion emulsion application and from the malathion-Kenite 2–I dust treatment (table 8). Similar results were obtained in tests conducted 1 month after treatment. After 3, 6, 9, and 12 months' storage, excellent kills of adult rice weevils were recorded in samples from both 2-pint malathion applications and from the malathion-Kenite 2–I dust treatment. However, the number of progeny gradually increased and a few of these emerging adults survived, even though the residue levels (table 4) were relatively high. The 1-pint malathion emulsion application did not control the rice weevils after 3 months' storage.

The malathion-Kenite 2–I dust application was the most effective treatment for killing red flour beetles and confused flour beetles throughout the test period (tables 9 and 10). Both of the 2-pint applications of malathion gave excellent kills of adult flour beetles for about 6 months, and greatly suppressed progeny development thereafter. The 1-pint malathion emulsion application, although suppressing progeny development for about 6 months, was not effective against adult flour beetles after 1 month's storage.

TABLE 8.—*RICE WEEVIL ADULTS: Average mortality after 21 days' exposure to samples of insecticide-treated grain sorghum and subsequent emergence of the F_1 progeny 63 days after infestation*

Insecticide and dosage per 1,000 bushels	Insects exposed for 21 days in grain sorghum samples taken after a storage period of—								
	24 hours			1 month			3 months		
	Mortality	Progeny [1] Total	Progeny [1] Dead	Mortality	Progeny [1] Total	Progeny [1] Dead	Mortality	Progeny [1] Total	Progeny [1] Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	100.0	0	—	100.0	0	—	100.0	30.0	100.0
Emulsion	100.0	0	—	100.0	0	—	100.0	39.4	100.0
1 pint, emulsion	100.0	19.8	100.0	99.6	19.2	100.0	99.3	326.6	64.0
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	13.8	100.0	100.0	4.6	100.0	100.0	34.4	100.0
Untreated check	1.5	1,215.2	1.3	1.4	1,487.0	1.4	3.0	889.2	.5

Insecticide and dosage per 1,000 bushels	Insects exposed for 21 days in grain sorghum samples taken after a storage period of—								
	6 months			9 months			12 months		
	Mortality	Progeny [1] Total	Progeny [1] Dead	Mortality	Progeny [1] Total	Progeny [1] Dead	Mortality	Progeny [1] Total	Progeny [1] Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	100.0	42.6	100.0	100.0	52.0	99.2	100.0	87.2	100.0
Emulsion	100.0	70.0	99.7	99.6	96.8	84.1	99.3	106.4	88.0
1 pint, emulsion	59.0	557.6	6.6	2.1	417.2	1.1	12.3	629.8	1.7
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	36.2	98.3	100.0	53.0	92.8	100.0	68.0	96.5
Untreated check	8.0	432.0	1.0	2.5	141.4	3.0	1.9	174.2	1.9

[1] Average number of progeny from each of 4 replicates of 50 insects.

The malathion-Kenite 2–I dust treatment was effective against the lesser grain borer throughout the 12-month storage period (table 11). Although a few progeny survived, damage to the grain was minimal. Malathion alone applied as a low-volume concentrate and as a water emulsion at the rate of 2 pints per 1,000 bushels was very effective for 6 months. After that its efficiency diminished, and the residues did not prevent progeny development. The 1-pint application of malathion as a water emulsion was ineffective after 1 month's storage.

Insect Damage

The extent of insect damage to the grain sorghum in storage depended largely on the number and species of insects that escaped being killed by the residues. Insects may inflict a certain amount of damage before being killed by materials applied as control measures. Assessments of the amount of damage to the grain sorghum were made by recording losses in test weight, determining the percentage of kernels damaged by insects, calculating the

TABLE 9.—*RED FLOUR BEETLE ADULTS: Average mortality after 21 days' exposure to samples of insecticide-treated grain sorghum and subsequent emergence of the F_1 progeny 63 days after infestation*

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	24 hours			1 month			3 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	100.0	0	—	100.0	0	—	98.9	0	—
Emulsion	100.0	0	—	100.0	0	—	98.5	0	—
1 pint, emulsion	99.6	0	—	97.7	0	—	16.2	0	—
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	0	—	100.0	0	—	99.6	0	—
Untreated check	1.2	42.0	0.5	0	49.9	1.0	.4	46.0	1.0

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	6 months			9 months			12 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	95.1	0	—	43.0	0	—	15.9	9.0	88.9
Emulsion	67.5	.2	0	31.2	1.0	100.0	7.7	8.0	75.0
1 pint, emulsion	9.6	9.8	0	12.4	141.4	4.7	12.3	80.6	23.1
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	0	—	99.2	4.4	100.0	93.1	0	—
Untreated check	4.2	58.6	.4	15.8	39.2	4.6	12.8	39.8	9.5

[1] Average number of progeny from each of 4 replicates of 50 insects.

kernel weight losses, recording the amounts of insect frass, and rating the visible damage by progeny in samples taken throughout the storage period.

Damage in terms of weight loss caused by insect feeding is important in evaluating the effectiveness of a protectant material as well as in determining the commercial grade of grain. The changes in the test weight of the grain sorghum are shown in table 12. The application of the malathion-Kenite 2–I dust initially reduced the test weight of the grain sorghum by about 2.2 pounds per bushel. The dust adheres to the kernels and affects the flowability, settling, and nestling qualities. Consequently, fewer kernels are found in a given volume. This measurable loss lowered the grade of the grain sorghum at the beginning. No significant test weight loss due to insect feeding was recorded later in this grain. Small weight losses were recorded in grain sorghum treated with the 2-pint applications of malathion. Grain from the emulsion treatment was damaged slightly more than that from the

TABLE 10.—*CONFUSED FLOUR BEETLE ADULTS: Average mortality after 21 days' exposure to samples of insecticide-treated grain sorghum and subsequent emergence of the F_1 progeny 70 days after infestation*

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	24 hours			1 month			3 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
Sprays:	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Malathion:									
2 pints:									
Concentrate	100.0	0	—	99.2	0	—	85.0	0	—
Emulsion	99.6	0	—	98.1	0	—	69.6	0	—
1 pint, emulsion	85.2	0	—	59.5	0	—	3.5	0	—
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	0	—	99.2	0	—	89.5	0	—
Untreated check	0	45.0	0	1.8	56.4	0.4	.4	76.2	1.0

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	6 months			9 months			12 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
Sprays:	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Malathion:									
2 pints:									
Concentrate	96.1	0	—	46.7	0.8	75.0	11.5	5.0	40.0
Emulsion	81.4	0	—	37.9	2.2	36.4	11.7	3.0	66.7
1 pint, emulsion	4.4	17.0	0	4.7	126.8	2.2	8.7	166.4	2.2
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	99.3	0	—	72.9	0	—	86.5	0	—
Untreated check	5.5	76.2	6.8	10.6	59.6	5.0	9.1	73.2	2.2

[1] Average number of progeny from each of 4 replicates of 50 insects.

concentrate treatment. Grain sorghum treated with the 1-pint malathion emulsion application was heavily damaged during the last 6 months of storage. The heavily damaged untreated grain sorghum lost more than 18 pounds per bushel.

Samples of 1,000 kernels from each of the bins were examined at the end of the 12 months' storage to determine the percentage of kernels damaged by insects and to calculate the kernel weight loss due to feeding of the insects. Kernels that are damaged by extensive internal feeding are often broken up during sampling and handling procedures, and, consequently, are not recorded by this method of determining the amount of kernel damage. The weight of undamaged, whole kernels passing over a 10-mesh screen averaged 0.0221 grams. The untreated grain sorghum had 97.12 percent of the kernels damaged during a 12 months' storage, with a calculated kernel weight loss of 46 percent (table 13). Damage to the kernels from the 1-pint malathion emulsion treatment was extensive. Nearly 74 percent of the kernels were damaged; the calculated weight loss was about 28.4 percent. In comparison, damage was relatively light in grain from the 2-pint malathion concentrate and emulsion treatments. They showed 8.40 and 13.36 percent of the kernels damaged, with

TABLE 11.—*LESSER GRAIN BORER ADULTS: Average mortality after 21 days' exposure to insecticide-treated grain sorghum and subsequent emergence of the* F_1 *progeny 63 days after infestation*

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	24 hours			1 month			3 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	100.0	0	—	100.0	0	—	99.3	0	—
Emulsion	100.0	0	—	100.0	0	—	99.7	11.0	72.7
1 pint, emulsion	100.0	2.0	50.0	95.3	26.0	65.4	70.0	129.0	13.2
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	100.0	10.0	20.0	100.0	6.0	100.0	100.0	13.0	100.0
Untreated check	4.9	1,118.0	1.5	7.5	1,173.2	3.9	3.5	1,741.2	5.8

Insecticide and dosage per 1,000 bushels	Insects released in grain sorghum after a storage period of—								
	6 months			9 months			12 months		
	Mortality	Progeny [1]		Mortality	Progeny [1]		Mortality	Progeny [1]	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Sprays:									
Malathion:									
2 pints:									
Concentrate	96.0	0.6	100.0	64.8	10.4	40.4	70.2	9.0	22.2
Emulsion	95.5	5.8	48.3	42.2	38.4	8.3	69.0	21.8	9.2
1 pint, emulsion	59.6	293.0	2.6	7.6	877.9	2.5	64.3	1,052.6	9.3
Dust:									
Malathion in Kenite 2–I, 1 pint in 112 pounds	97.9	2.0	90.0	91.0	17.0	48.2	96.3	11.8	54.2
Untreated check	6.0	666.0	4.5	16.3	243.6	5.3	22.1	100.2	5.1

[1] Average number of progeny from each of 4 replicates of 50 insects.

weight losses of 2.29 and 3.40 percent, respectively. Grain from the malathion-Kenite 2–I dust treatment had about 9.4 percent of the kernels damaged, with a weight loss of about 3.1 percent.

The amounts of fine dusts, consisting primarily of insect frass, that were sifted from the 1-gallon samples collected as the bins were emptied at the end of the storage period indicated the amount of insect activity and damage to the grain during the 12 months (table 14). Very large amounts of dust were obtained from the untreated check bins, because of the activity of the large populations of insects infesting these bins and damaging practically all of the kernels. Relatively large amounts of dust were recovered from the samples of grain treated with the 1-pint dosage of malathion as an emulsion. The very small amounts recovered from the grain treated with the 2-pint malathion concentrate and the malathion-Kenite 2–I correlate well with the extent of damage to the kernels. A slightly larger amount was found in the samples from the 2-pint malathion emulsion treatment.

Insect Emergence

The extent of the infestations that had been established in the bins of grain sorghum by

TABLE 12.—*Test weights per bushel of samples of insecticide-treated grain sorghum at given intervals during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Before treatment	Immediately after treatment	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months	Loss during storage
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Sprays:								
Malathion:								
2 pints:								
Concentrate	58.49	58.91	58.53	58.53	58.28	57.50	57.62	0.87
Emulsion	58.71	58.75	58.34	58.40	58.22	57.24	57.42	1.29
1 pint, emulsion	58.79	59.10	58.51	58.53	56.20	52.11	49.75	9.04
Dust:								
Malathion in Kenite 2–I, 1 pint in 112 pounds	58.45	56.19	55.87	56.20	56.45	56.20	56.25	[1] 2.20
Untreated check	58.41	—	57.87	55.56	48.08	40.78	39.93	18.48

[1] The initial loss of 2.26 pounds during treatment was caused by the addition of the diatomaceous earth.

TABLE 13.—*Kernel damage and calculated weight loss of samples of insecticide-treated grain sorghum during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Kernels damaged in sample—					Weight loss [1]
	Before treatment	After 3 months	After 6 months	After 9 months	After 12 months	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	2.08	4.24	5.92	8.40	2.29
Emulsion	0	3.20	7.68	8.72	13.36	3.40
1 pint, emulsion	0	10.16	27.60	45.28	73.96	28.36
Dust:						
Malathion in Kenite 2–I, 1 pint in 112 pounds	0	1.84	5.76	9.20	9.44	3.13
Untreated check	0	27.60	64.64	78.48	97.12	46.00

[1] Weight of undamaged whole kernels averaged 0.0221 gram.

the end of the study is shown by the emergence of insects from samples taken as the bins were emptied. All bins were infested (table 15). The fewest insects emerged from the samples with the malathion-Kenite 2–I dust treatment. Larger numbers emerged from the grain treated with 2-pint malathion concentrate and emulsion. Emergence from samples from bins treated with 1-pint of malathion emulsion was greater than from the heavily damaged untreated check lots.

Damage by Progeny

The visible damage by insect progeny to samples probed from the bins during the 12 months' storage period indicate that the residues from both 2-pint applications of malathion were completely effective in preventing infestations for 9 months and that infestations were greatly suppressed during the last 3 months (table 16). The malathion in Kenite 2–I dust treatment was somewhat less effective in preventing infestations, but did suppress the amount of damage. Residues resulting from the 1-pint malathion emulsion did not satisfactorily suppress the establishment of active rice weevil populations after 1 month's storage. Red flour beetles, confused flour beetles, and lesser grain borers were quite numerous in these bins during the last 6 months of storage.

TABLE 14.—*Weight of insect frass per gallon sample of insecticide-treated grain sorghum after 12 months' storage*

Insecticide and dosage per 1,000 bushels	Average	Range
	Grams	*Grams*
Sprays:		
Malathion:		
2 pints:		
Concentrate	3.29	1.3– 8.2
Emulsion	8.70	2.1– 23.9
1 pint, emulsion	188.64	43.3–387.0
Dust:		
Malathion in Kenite 2–I, 1 pint in 112 pounds	4.00	1.5– 10.1
Untreated check	819.26	638.0–992.1

TABLE 15.—*Emergence of live adult insects from 1-gallon samples of insecticide-treated grain sorghum after 12 months' storage* [1]

Insecticide and dosage per 1,000 bushels	Rice weevils	Flour beetles	Lesser grain borers	Others	Total
	Number	*Number*	*Number*	*Number*	*Number*
Sprays:					
Malathion:					
2 pints:					
Concentrate	11.5	1.9	27.3	0.6	41.3
Emulsion	20.6	4.1	52.5	0	77.2
1 pint, emulsion	196.5	58.9	219.9	2.6	477.9
Dust:					
Malathion in Kenite 2–I, 1 pint in 112 pounds	9.7	0	8.8	.2	18.7
Untreated check	5.6	15.8	260.5	.5	282.4

[1] Samples held for 45 days for emergence at end of 12 months' storage period.

In addition to the data on mortality and F_1 progeny development recorded during the toxicity studies, estimates were made of the extent of damage caused by the establishment of infestations by the progeny when these samples were held for 120 days after infestation of the subsamples. Tables 17 to 20, inclusive, show these estimates. The 2-pint applications of malathion and the malathion-Kenite 2–I dust treatments were very effective in controlling or suppressing damage by rice weevils (table 17); however, damage by the lesser grain borer was more evident (table 20). The 1-pint malathion emulsion application did not give the desired protection after 1 month's storage. Red flour beetle and confused flour beetle progeny were controlled by both of the 2-pint malathion applications and the mala-

TABLE 16.—*Visible damage by insect progeny in samples of insecticide-treated grain sorghum composited from bin probings made during 12 months' storage*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0	0	0.4
Emulsion	0	0	0	0	0	.8
1 pint, emulsion	0	0	2.6	3.0	3.8	5.0
Dust:						
Malathion in Kenite 2–I, 1 pint in 112 pounds	0	0	0	.6	.4	.4
Untreated check	0	5.0	4.8	[2] 5.0	[2] 5.0	[2] 5.0

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

[2] All samples grade 5 when observed 90 days after sampling.

TABLE 17.—*Visible damage by rice weevil progeny in samples of insecticide-treated grain sorghum after toxicity tests*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months[2]
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0	0	0.2
Emulsion	0	0	0	.2	.8	.8
1 pint, emulsion	0	0	4.0	5.0	4.4	5.0
Dust:						
Malathion in Kenite 2–I, 1 pint in 112 pounds	0	0	0	0	0	.4
Untreated check	4.4	4.0	[3] 5.0	[3] 5.0	4.0	3.6

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

[2] Reading made 90 days after infestation.

[3] All samples grade 5 when observed 105 days after infestation.

thion-Kenite 2–I dust treatments (tables 18 and 19).

Damage by rice weevil progeny to samples with the 1-pint malathion emulsion treatment, infested during the food selection study exposures, indicated that the grain was not protected after 3 months' storage (table 21). Both 2-pint applications of malathion and the malathion-Kenite 2–I dust treatment gave excellent protection; however, a few weevils survived the killing action of the residues in the samples exposed 12 months after treatment.

TABLE 18.—*Visible damage by red flour beetle progeny in samples of insecticide-treated grain sorghum after toxicity tests*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months[2]
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0	0	0
Emulsion	0	0	0	0	0	0
1 pint, emulsion	0	0	0	1.2	3.2	2.8
Dust:						
Malathion in Kenite 2–I, 1 pint in 112 pounds.	0	0	0	0	0	0
Untreated check	1.8	2.0	2.4	2.4	2.0	2.4

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

[2] Reading made 90 days after infestation.

TABLE 19.—*Visible damage by confused flour beetle progeny in samples of insecticide-treated grain sorghum after toxicity tests*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months[2]
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0	0	0
Emulsion	0	0	0	0	.4	0
1 pint, emulsion	0	0	0	1.0	3.0	3.2
Dust:						
Malathion in Kenite 2–I, 1 pint in 112 pounds	0	0	0	0	0	0
Untreated check	2.2	2.6	2.8	2.4	2.4	2.2

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

[2] Reading made 90 days after infestation.

TABLE 20.—*Visible damage by lesser grain borer progeny in samples of insecticide-treated grain sorghum after toxicity tests*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months[2]
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0.4	1.2	1.2
Emulsion	0	0	.6	1.2	2.2	2.0
1 pint, emulsion	.2	.6	3.4	4.6	5.0	5.0
Dust:						
Malathion in Kenite 2-I, 1 pint in 112 pounds	0	0	0	0	.8	1.0
Untreated check	5.0	5.0	4.8	4.6	3.8	3.6

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.
[2] Reading made 90 days after infestation.

TABLE 21.—*Visible damage by rice weevil progeny in samples composited from insecticide-treated grain sorghum exposed in food preference studies*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after infestation of samples taken after a storage period of—[1]					
	24 hours	1 month	3 months	6 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
Sprays:						
Malathion:						
2 pints:						
Concentrate	0	0	0	0	0	0.2
Emulsion	0	0	0	0	0	.4
1 pint, emulsion	.2	0	2.6	4.6	4.8	5.0
Dust:						
Malathion in Kenite 2-I, 1 pint in 112 pounds.	0	0	0	0	0	.2
Untreated check	5.0	5.0	5.0	4.8	4.2	3.8

[1] Damage rating code: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amounts of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

FINDINGS

A study was made of the effectiveness of several different malathion formulations applied as a protectant to grain sorghum stored in small bins. All bin lots were equally exposed to infestation by mixed populations of insects. There was a good correlation between the results obtained from the different methods of evaluation. The following conclusions were drawn from these tests:

(1) Malathion applied as a concentrate at a dosage of 2 pints per 1,000 bushels of grain sorghum gave excellent protection when the grain was continuously exposed to mixed populations of insects for 12 months.

(2) The 2-pint malathion concentrate application protected and maintained the quality and grade of the grain sorghum better than other malathion formulations.

(3) The residues resulting from the 2-pint malathion concentrate application degraded from 19.74 p.p.m. to 3.44 p.p.m. during the 12 months of storage.

(4) The application of the malathion-Kenite 2–I dust reduced the test weight of the grain about 2.2 pounds per bushel and consequently lowered the commercial grade.

(5) Except for the reduction in test weight that affected the numerical grade, the malathion-Kenite 2–I dust treatment gave protection about equal to that from the 2-pint malathion concentrate application.

(6) The malathion residues resulting from the malathion-Kenite 2–I dust treatment degraded from 9.62 p.p.m. to 2.12 p.p.m. during the 12 months of storage.

(7) The application of 2 pints of malathion per 1,000 bushels as a water emulsion was only slightly less effective overall than the malathion concentrate and malathion-Kenite 2–I dust treatments.

(8) The malathion residues resulting from the 2-pint malathion application as an emulsion degraded from 18.28 p.p.m. to 3.08 p.p.m. during the 12 months of storage.

(9) The malathion-Kenite 2–I dust treatment was effective in toxicity tests with rice weevils and lesser grain borers, giving results comparable to both of the 2-pint malathion treatments. It surpassed both 2-pint applications in bioassays with red flour beetles and confused flour beetles throughout the storage period.

(10) The 1-pint malathion emulsion treatment did not satisfactorily protect the grain sorghum.

APPENDIX

Characteristics of Inert Dust

Kenite 2–I:

Moisture, percent	8
Retained on 200-mesh screen, percent	Less than 3
Retained on 325-mesh screen, percent	Less than 10
Silica (SiO_2), percent	88
Surface area, sq. cm. per gram	30,000
Brightness, photovolt	70
pH (approx.)	7
Dry density, lb. per cu. ft	Min. 14, Max. 15

Grading of Grain Containing Foreign Substances

Instructions for grading grain containing foreign substances are given in GR Instruction 918-6 Aux. 1.[2] Grain that contains an unknown foreign substance is graded "Sample Grade," except when the foreign substance is identified as a diatomaceous earth. An applicant for inspection of grain that contains or appears to contain diatomaceous earth may file a written application with the grain inspector for an examination to determine the presence of a diatomaceous earth. If the inspector determines that the grain contains no unknown foreign substance other than diatomaceous earth, he will grade the grain as though it contained no unknown foreign substance.

A thorough understanding of the grading instructions is needed before applying a diatomaceous earth to grain. Although diatomaceous earth is exempt from the requirement of a tolerance for residues on stored grain, an established tolerance of 8 p.p.m. of malathion is in effect.

[2] UNITED STATES DEPARTMENT OF AGRICULTURE. GRADING AND CERTIFICATION OF GRAIN CONTAINING DIATOMACEOUS EARTH. U.S. Dept. Agr., Agr. Mktg. Serv., Grain Division, GR Instruction, 918-6, Aux. 1, 6 pp., illus. 1963.

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